

REMARKS

In order to effect entry and full consideration of the foregoing amendments and following comments, the present amendment is being filed as a Preliminary Amendment and accompanied by a Request For Continued examination. According, prompt and full consideration of this response is earnestly solicited.

The Official Action, dated February 12, 2004 has been received and its contents carefully noted. In view thereof, claims 1-3 and 11-13 have been canceled, claims 4-8 have been amended and new claims 17-21 have been added in order to better define that which Applicants regard as the invention. Accordingly, claims 4-8, 10 and 17-21 are presently pending in the instant application.

In reviewing the Official Action:

Claims 1-8 and 10-13 continue to be rejected under 35 U.S.C. § 103(a), as being obvious in view of the teachings of Tung ('625) combined with the teachings of Sugano et al et al ('527), and

Claims 1-8 and 10-13 continue to be rejected under 35 U.S.C. § 103(a), as being obvious in view of the teachings of Maa et al ('775) combined with the teachings of Sugano et al et al ('527).

These rejections are respectfully traversed in so far as they may apply to new claims 17-21 as well as claims 4-8 and 10 which are either directly or indirectly dependent thereon.

With reference to new independent claims 17 and 18, the inventions of claims 17 and 18 are described in embodiment 3 and shown in Figs, 5(c) – 7(b) of the present specification.

As shown in Fig. 6(a), the silicon oxide film 209 is formed on semiconductor layers such as the gate electrode 205 and the high concentration impurity layer 208 shown in Fig. 5(c). Next, as shown in Fig. 6(b), a particle energy beam including a nonmetal element, such as an Ar ion beam, is irradiated from above the silicon oxide film 209 at a low energy. In this manner, owing to recoil of the particle energy beam, oxygen atoms included in the silicon oxide film 209 are distributed in regions in the vicinity of the surfaces of the high concentration impurity layer 208 and the gate electrode 205, so as to form an oxygen atom distributed region 210 as is shown in Fig. 6(c).

The silicon oxide film 209 shown in Fig. 6(b) is then removed after the forming of the oxygen atom distributed region 210.

Subsequently, as shown in Fig. 7(a), a metal film such as the cobalt film 211 is formed over the high concentration impurity layer 208 and the gate electrode 205 in which the oxygen atom distributed region 210 is formed. Accordingly, a cobalt disilicide is formed on the interface between the high concentration impurity layer 208 and the cobalt film 211 and the interface between the gate electrode 205 and the cobalt film 211, respectively. Thereafter, the cobalt film 211 is removed as shown in Fig. 7(b).

Clearly, this method of forming a semiconductor as set forth in claims 17 and 18 is neither disclosed in nor remotely suggested by the prior art combinations proposed by the Examiner.

U.S. Patent No. 5,728,625 issued to Tung teaches forming a thin oxide layer 200 on the surface of a silicon substrate 210. The oxide layer 200, which is of a thickness in the range of 0.5 to about 1.5 nm or less, is formed by subjecting the surface of the substrate to a chemical cleaning solution as noted in col. 5, lines 33-39. Next, a cobalt layer 220 is formed over the oxide layer 200. The cobalt layer 220 has a uniform thickness and is formed on the surface of the substrate using e-beam evaporation or sputter deposition as discussed in col. 5, lines 62-66. After the cobalt layer 220 is formed on the substrate, the substrate is then annealed. The substrate is annealed for an amount of time that is sufficient to convert the cobalt to cobalt silicide as referred to in col. 6, lines 11-19.

With respect to the disclosure of U.S. Patent No. 4,469,527 issued to Sugano et al., a silicon substrate 32 having a silicon oxide(SiO_2) film 31 on the surface thereof as shown in Fig. 15A is irradiated with thermal neutron beams, so that lattice defects are produced throughout the silicon substrate 32 to make it semi-insulating as shown in Fig. 15B. The surface of the silicon substrate 32 is annealed by irradiating it with laser beam pulses, so that an activated layer 33 is formed at the surface portion of the silicon substrate 32 adjacent the silicon oxide film 31, as shown in Fig. 15C. Subsequently, the silicon oxide film 31 is removed and ohmic contacts 34 are formed in two locations as shown in Fig. 15D and discussed in detail at col. 11, line 67 – col. 12, line 11.

U.S. Patent No. 5,830, 775 to Maa et al. teaches, providing an active area 32 on an oxide layer. 14 formed on a substrate 10, as shown in Fig. 2. Maa further teaches forming a gate structure 30, and a source 46 and a drain 48 (see col. 3, lines 52-65). Next, a silicide metal 80 is formed as shown in Fig. 4 and disclosed in col. 4, line 55 – col. 5, line 4 of the reference. RTA is then performed in a chamber 85, and silicide is formed at the boundaries

90 between the silicide metal 80 and silicon regions 40, 46 and 48, as shown in Fig. 5 (see col. 5, lines 5-16).

Unlike the present invention, according to Jung, the thin oxide layer 200 is formed on the surface of the silicon substrate 210. Thereafter, the cobalt layer 220 is formed on the oxide layer 200. The cobalt layer 220 is formed on the surface of the substrate by e-beam evaporation or sputter deposition.

On the other hand, according to the present invention, the silicon oxide film 209 is formed on semiconductor layers such as the gate electrode 205 and the high concentration impurity layer 208, and metal film such as the cobalt film 211 is formed after the silicon oxide film 209 is removed.

Further, with the present invention, in order to perform an excellent epitaxial growth for a cobalt silicide film, oxygen atoms are distributed in the vicinity of the surface portion of the semiconductor layer through recoil by irradiating the silicon oxide film 209 with a particle energy beam including a nonmetal element, before removing the silicon oxide film 209.

Tung fails to disclose distributing oxygen atoms in the vicinity of the surface of the semiconductor layer using the recoil of the particle energy beam, and thus is different from the present invention.

By utilizing the recoil of the particle energy beam such as in the present invention, oxygen atoms can be distributed to the shallow region of the semiconductor layer. Accordingly, the silicon atoms in the vicinity of the surface can be replaced by the oxygen atoms, and the amount of silicon atoms in contact with the cobalt atoms can be reduced. Hence, abrupt reaction between the cobalt atoms and the silicon atoms can be prevented, and an excellent epitaxial growth can be achieved.

As to the teachings of Sugano, the substrate on which the oxide film is formed is irradiated with thermal neutron beam and laser beam pulses. Specifically, the silicon substrate 32 having the oxide film 31 on the surface thereof is irradiated with thermal neutron beams, so that lattice defects are produced. In addition, laser beam pulses are irradiated to form the activated layer 33 at the surface portion of the silicon substrate 32 adjacent to the oxide film 31.

On the other hand, according to the present invention, the silicon oxide film 209 is formed on semiconductor layers such as the gate electrode 205 and the high concentration impurity layer 208, and metal film such as the cobalt film 211 is formed after the silicon oxide film 209 is removed.

Moreover, in the present invention, in order to perform an excellent epitaxial growth for a cobalt silicide film, oxygen atoms are distributed in the vicinity of the surface portion of the semiconductor layer through recoil, before forming the metal film, by irradiating the silicon oxide film 209 with a particle energy beam including a nonmetal element, before removing the silicon oxide film 209.

Sugano teaches producing lattice defects by irradiating the substrate with thermal neutron beams, and forming the activated layer at the surface portion of the substrate. However, Sugano fails to disclose distributing oxygen atoms in the vicinity of the surface of the semiconductor layer using the recoil of the particle energy beam, and forming the cobalt silicide film, and thus fails to disclose or suggest that set forth in accordance with Applicants' claimed invention.

Again, by utilizing the recoil of the particle energy beam such as in the present invention rather than a thermal neutron beam, damages such as lattice defects will not occur on the semiconductor layer. Accordingly, since no lattice defect is formed in the vicinity of the surface of the substrate and the oxygen atoms can be distributed, abrupt reaction between the cobalt atoms and the silicon atoms will not occur. In other words, a uniform epitaxial growth of cobalt silicide can be achieved.

As to the teachings of U.S. Patent No. 5,830,775 to Maa, a diffusion layer is formed on the oxide film formed on the semiconductor substrate. Specifically, the oxide film is formed within single crystal Si, and the diffusion layer is formed on the single crystal Si layer on the oxide film. In other words, the oxide film formed in the semiconductor layer is provided for forming the diffusion layer. Moreover, a metal film is formed on the diffusion layer, and RTA is performed and silicide is formed.

On the other hand, according to the present invention, as noted previously, the silicon oxide film 209 is formed on semiconductor layers such as the gate electrode 205 and the high concentration impurity layer 208, and metal film such as the cobalt film 211 is formed after the silicon oxide film 209 is removed.

Further, with the present invention, in order to perform an excellent epitaxial growth for a cobalt silicide film, oxygen atoms are distributed in the vicinity of the surface portion of the semiconductor layer through recoil, before forming the metal film, by irradiating the silicon oxide film 209 with a particle energy beam including a nonmetal element, before removing the silicon oxide film 209.

While Maa may teach forming the diffusion layer on the oxide film formed on the semiconductor substrate, Maa fails to disclose distributing oxygen atoms in the vicinity of the surface of the semiconductor layer using the recoil of the particle energy beam, and thus is different from the presently claimed invention.

Once again, by utilizing the recoil of the particle energy beam such as in the present invention, oxygen atoms can be distributed to the shallow region of the semiconductor layer. Accordingly, the silicon atoms in the vicinity of the surface can be replaced by the oxygen atoms, and the amount of silicon atoms in contact with the cobalt atoms can be reduced. Hence, abrupt reaction between the cobalt atoms and the silicon atoms can be prevented, and an excellent epitaxial growth can be achieved.

Finally, since Tung, Sugano et al. and Maa et al are deficient for the reasons discussed in detail hereinabove, the references cannot be combined with proper motivation to (explicitly or inherently) teach or suggest the presently claimed invention. Further, even if combined, the combination would not yield a process as presently claimed since the combinations fail to disclose distributing oxygen atoms in the vicinity of the surface of the semiconductor layer using the recoil of the particle energy beam, and thus the combinations proposed by the Examiner are different from the presently claimed invention.

With respect to new independent claim 21, this claim too recites a method for fabricating a semiconductor device comprising the steps of distributing an oxygen element in a region in the vicinity of a surface portion of a semiconductor layer; depositing a metal film on said semiconductor layer; and epitaxially growing a semiconductor-metal compound layer in the surface portion of said semiconductor layer by causing a reaction between an element included in said semiconductor layer and a metal included in said metal film through annealing carried out on said metal film; wherein said region in the vicinity of the surface portion of said semiconductor layer is within a depth of 0.5 nm to 5 nm from the surface of the semiconductor layer; and a dosage of said nonmetal element per unit area is between $4 \times 10^{14} \text{ cm}^{-2}$ and $4 \times 10^{15} \text{ cm}^{-2}$. Accordingly, in that the combinations proposed by the Examiner

fail to disclose distributing an oxygen element in a region in the vicinity of a surface portion of the semiconductor layer and epitaxially growing a semiconductor-metal compound layer in the surface portion of the semiconductor layer by causing a reaction between an element included in the semiconductor layer and a metal included in the metal film through annealing being carried out on said metal film, with the region in the vicinity of the surface portion of the semiconductor layer being within a depth of 0.5 nm to 5 nm from the surface of the semiconductor layer; and the dosage of the nonmetal element per unit area being between $4 \times 10^{14} \text{ cm}^{-2}$ and $4 \times 10^{15} \text{ cm}^{-2}$, claim 21 is likewise believed to be in proper condition for allowance.

Having responded to the rejections set forth in the outstanding Final Office Action, it is submitted that claims 4-8, 10 and 17-21 are now in condition for allowance. An early and favorable Notice of Allowance is respectfully solicited. In the event that the Examiner is of the opinion that a brief telephone or personal interview will facilitate allowance of one or more of the above claims, the Examiner is courteously requested to contact Applicants' undersigned representative.

Respectfully submitted,



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